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RESEARCH

Investigation of corrosion resistance of steel used in beet sugar processing juices

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Abstract In this study, corrosion behaviors of materials used in diffusion units and equipment used in juice clarification steps and tubes in evaporators at Ankara Sugar Factory were investigated in terms of juice production and juice clarification processes as well as juice medium at evaporation stages. The measurements have been performed by comparing steel types used in these units and alternative types of steels that can also be used during the study. For this purpose, pH and Brix (Bx, refractometric dry matter) values of raw juice, thin juice and juice taken from evaporator have been measured during 2009–2010, 2010–2011, and 2011–2012 campaign periods of Ankara Sugar Factory. In addition to these measurements, traditional weight loss and electrochemical tests such as Linear Polarization Resistance (LP), Tafel Extrapolation (TP), Electrochemical Impedance Spectroscopy (EIS) were performed to measure and compare the corrosion rate of the metals used in different juice mediums. The metals included in the study were AISI 316L, AISI 304L grade stainless steel, St 37.2 grade carbon steel and nickel-coated St 37.2. The highest and the lowest corrosion rates were recorded for raw juice and thin juice, respectively. St 37.2 steel had the fastest corrosion rate, whereas the stainless steel AISI 316L has the slowest corrosion rate. However, AISI 316L shows only slightly higher corrosion resistance compared to the corrosion resistance of AISI 304L in different juices. Therefore, AISI 304L steel, which is cheaper than AISI 316L, can be selected as a substation of St 37.2 steel.

Keywords Beet sugar juice · Alloys · Corrosion · Electrochemical Methods

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Introduction

Along with the development of sugar industry, corrosion has drawn attention in sugar industry and in terms of corrosion, various stages of corrosion are analyzed with regards to material and environment by many researchers. Common types of corrosion seen in processing of sugar are bacterial corrosion, erosion corrosion, pitting corrosion, stress corrosion and high temperature corrosion [1–3]. In Ankara Sugar Factory, most of the equipment parts are made of St 37.2 type steel because of its low cost, good mechanical properties and ease of fabrication. However, corrosion is a major problem in Ankara Sugar Factory due to the relatively low corrosion resistance of St 37.2 type steel. Maintenance, replacement and repair of equipment due to corrosion and abrasion have diverse effect on the operating cost. Therefore, the use of stainless steel such as AISI 304L and AISI 316L that have better corrosion resistance for various processing industries as a construction material in sugar factory can minimize these operating costs. For this reason, most sugar mills around the world have switched over the components made of various grades of stainless steel [4]. Corrosion resistance of steels in juice medium should be evaluated to choose the proper materials that can be used in a sugar factory. Corrosion in sugar factories can arise mainly due to the presence of some acids, impurities in juice and high temperature [5]. Some process parameters such as pH, temperature, dissolved oxygen content, brix and conductivity values of juices also affect the corrosion rate of steel [6–9]. The aim of performing corrosion tests in equipment is determining the best specifications of the materials, probable service life of the equipment or products, most economical means for reducing corrosion and studying the corrosion mechanism [10]. Corrosion rate measurement by weight loss of coupon specimens especially for the uniform corrosion is the simplest and the best service condition technique. For this reason, weight loss corrosion tests are performed regularly in different types of juices produced in Ankara Sugar Factory and in boiler water mediums. However, electrochemical corrosion rate measurement techniques such as Tafel Analysis, Linear Polarization and Electrochemical Impedance Spectroscopic measurements are not conducted regularly. Though numerous studies are made on the corrosion resistance of stainless steel in different corrosive mediums including sugarcane juice, investigation on the comparative corrosion resistance study of AISI 304L, AISI 316L types stainless steel, nickel-coated St 37.2 steel and St 37.2 steel in different types of juices taken from Ankara Sugar Factory does not exist. In the present study, it was aimed to measure corrosion resistance of St 37.2, nickel-coated St 37.2, AISI 304L, AISI 316L stainless steel in different types of juices produced in Ankara Sugar Factory using weight loss immersion test, Tafel Analysis, Linear Polarization Resistance and Electrochemical Impedance Spectroscopy.

Materials and methods

Materials

The studied steels were stainless steel AISI 316L, AISI 304L and carbon steel St 37.2. They were received from Ankara Sugar Factory. Table 1 provides the details of their chemical composition.

Weight loss corrosion test

ASTMD 3263 was followed as a guide for weight loss immersion tests [11]. Two specimens of each materials were prepared in a rectangular size of 10 × 3.5 × 0.15 cm. Corrosion rate of the steel samples was calculated by:

Corrosion rate (mm/year): $(W_i - W_f)$ 24.365/A.T.7830
W_i: initial weight (g) A: surface area (m^2)
W_f: final weight (g) T: time (hour)
(mpy = 0.0254 mm/year)

Electrochemical measurements

Electrochemical tests were performed to determine the corrosion rate of AISI 304L, AISI 316L stainless steels, St 37.2 low carbon steel and nickel-coated St37.2 in different types of juices produced during three campaign periods in Ankara Sugar Factory. St 37.2 electrode was electroless nickel-coated according to the procedure given in the literature Surface and Coating Technology 201 (2006)90–101 [12]. For this purpose, electrochemical experiments were conducted using Gamry Reference 600 potentiostat galvanostat/ZRA system with Gamry Framework/Echem Analyst (Version 5.50) software. A platinum electrode that has a surface area of 1.5 cm^2 was used as the counter electrode and a saturated calomel electrode (SCE) was used as the reference electrode. Working electrodes were AISI 316L, AISI 304L, St 37.2 and nickel-coated St 37.2 steels with an area of 4.9 cm^2. The surfaces of the working electrodes were polished to mirror brightness with a polishing cloth using 3, 1, 0.05 microns of aluminum polishing solutions, respectively. The electrolytic cell was made of a 750 ml Pyrex glass flask with four entrances for reference electrode, working electrode, counter electrode and aeration/deaeration. Measurements were conducted in aerated and unstirred solutions. The mounted samples were immersed in juice medium to obtain a constant potential, which is referred as the Open Circuit Potential. About 30 min was sufficient to attain constant potential condition. In all cases, Open Circuit Potential was established first, and then the experiments were carried out. Electrochemical Impedance Spectroscopy was performed using a potential amplitude of 10 mV and the frequency ranging from 100 kHz to 5 mHz. EIS data were analyzed using the ZSimpwin 3.10 program which provided accurate information about the circuit. The impedance data were analyzed using the electrical equivalent circuit R(QR) presented in Fig. 2. The measure of goodness of fit of the model was the χ^2 parameter; during the analysis, χ^2 did not exceed 1×10^{-4}, attesting to a very high fit of received impedance spectra to the proposed electrical equivalent circuit. The same circuit has also been used in similar aggressive environments [13].

Table 1 Composition of steels (wt %)

Grade of steel	C	Cr	Ni	Mo	Mn	P	Si	S	Cu
St 37.2	0.063	0.016	0.018	0.014	0.528	–	0.181	0.012	0.047
AISI 304L	0.03	18–20	8–12	–	0.045	1	2	0.03	–
AISI 316L	0.03	16–18	10–14	2–3	2	0.045	0.75	0.03	–

Table 2 The results of weight loss corrosion test obtained in juice samples taken from various units during 2009–2010 campaign period

Juice	Metals	Briks	pH	Corrosion rate determined by weight loss test (mpy)
Raw juice	AISI 304L	16.52	6.75	0.0042
Raw juice	AISI 316L	16.52	6.75	0.0037
Thin juice	AISI 304L	15.82	8.75	0.0025
Thin juice	AISI 316L	15.82	8.75	0.0025
2A Evap.	AISI 304L	35.50	8.79	0.0021
2A Evap.	AISI 316L	35.50	8.79	0.0020

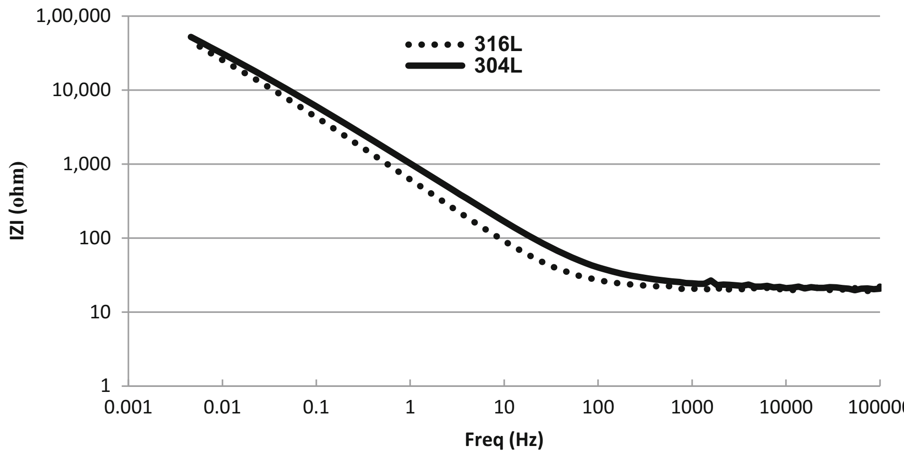


Fig. 1 The *Bode curves* of AISI 304L and AISI 316L electrodes in raw juice

The Linear Polarization Technique was applied using a scan rate of 0.125–1 mV/s and a polarization of ±10 mV in relation to the Open Circuit Potential. The parameters of Tafel analysis were a scan rate of 1 mVs and a polarization of ±600 mV (Open Circuit Potential).

Results and discussion

Corrosion behavior of St 37.2, nickel-coated St 37.2, AISI 304L and AISI 316L stainless steel in different types of juices produced in Ankara Sugar Factory was studied during 2009–2010, 2010–2011, and 2011–2012 campaign periods. For this purpose, pH, Brix (Bx, refractometric dry mater) values of thin juice, juice from diffusion unit, juice from clarification stages have been measured. In addition, weight loss, EIS, LP and Tafel analysis were performed to determine the corrosion rates of the studied materials in juice medium.

Results of measurements conducted during 2009–2010 campaign period

In this campaign period, corrosion resistance of AISI 304L and AISI 316L steels for substitution of St 37.2 using weight loss, EIS, LP, and Tafel analysis was evaluated.

In Table 2, corrosion rates of steels determined by weight loss measurement technique are presented. It can be observed that highest corrosion rates were recorded in raw juice followed by thin juice and the lowest corrosion rates were recorded in juice taken from 2A evaporator, respectively. In the factory, juice temperature in 2A evaporators reaches up to a degree ranged between 130 and 140 °C. In fact, corrosion rates in such high temperature levels should be much higher than the corrosion rates measured in the laboratory conditions (e.g., 25 °C). However, it was not possible to generate such a high temperature in the laboratory conditions. As it can be seen from Table 2, the highest brix content is in juice taken from 2A evaporators and this causes measured corrosion rates in this medium at room temperature to be the lowest.

Figure 1 shows the Bode plots of AISI 304L and AISI 316L steels obtained in raw juice. Slightly higher impedance modulus was recorded for AISI 316L which implies that AISI 316L has slightly higher corrosion resistance compared to AISI 304L in raw juice. Similar Bode plots were also obtained for EIS measurements conducted in thin juice and juice taken from 2A evaporators (measurements were taken at room temperature). In these mediums, AISI 316L shows slightly higher corrosion resistance compare to the corrosion resistance of AISI 304L. Impedance data were analyzed using an electrical equivalent circuit R(QR) illustrated in Fig. 2.

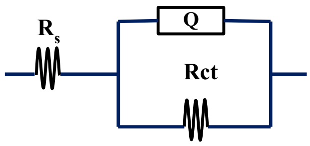


Fig. 2 Equivalent circuit R(QR) used to simulate EIS data

In the equivalent circuit used for analyzing impedance plot, R_s denotes solution resistance, R_{ct} denotes charge transfer resistance of corroding metal and Q reflects constant phase element of corroding metal–solution interface. The values of impedance parameters derived from the fitting of equivalent circuits to experimental data are given in Table 3.

Polarization resistance measurement was also conducted for AISI 304L and AISI 316L type steels for the corrosion measurements in various juices. However, nonlinear behavior of E–I curves in the potential region ±20 mV with respect to corrosion potentials were recorded. Relatively, high corrosion rate or active dissolution condition is needed to observe linear behavior in E–I plots during polarization resistance measurements. Departure from linearity appears when absolute values of the Tafel constants are low as $\beta_a = \beta_c = 30$ mV. Unequal Tafel constants further compress the range of apparent linearity and also result in asymmetry about origin when $\beta_a = 30$ mV and $\beta_c = 118$ mV [11].

Potentiodynamic polarization measurements were conducted for AISI 316L and AISI 304L steels in different juice mediums and Fig. 3 shows the polarization curves recorded in raw juice. However, Tafel analysis was not conducted for determination of the corrosion rates since at least one decade of linearity on E–log I curves is desirable for maximum accuracy to determine i_{corr} by Tafel extrapolation [14]. Lower current densities and more anodic E_{ocp} values were recorded for AISI 316L. Corrosion resistance of AISI 316L and AISI 304L in different types of juices obtained from weight loss, EIS and potentiodynamic measurements shows that AISI 316L has only slightly higher resistance. Thus, the use of AISI 304L which is cheaper than AISI 316L can be envisaged as substation of St 37.2 steel.

Table 3 The EIS circuit analysis results obtained in juice samples taken from various units during 2009–2010 campaign period by fitting the impedance spectra to the R(QR) circuit

	Metals	Briks	pH	R_s (kΩ cm^2)	Q (Ss^{-n}/cm^2)	n	R_{ct} (kΩ cm^2)	χ^2
Raw juice	AISI 304L	16.5	6.8	0.0207	0.00034	0.85	259.5	1.67×10^{-4}
Raw juice	AISI 316L	16.5	6.8	0.0022	0.00023	0.79	261.5	2.58×10^{-4}
Thin juice	AISI 304L	15.8	8.8	0.0168	0.00017	0.71	294.8	3.55×10^{-4}
Thin juice	AISI 316L	15.8	8.8	0.0172	0.00025	0.80	295.2	1.11×10^{-4}
2A Evap.	AISI 304L	35.5	8.8	0.0149	0.00025	0.79	365.0	9.05×10^{-4}
2A Evap.	AISI 316L	35.5	8.8	0.0149	0.00036	0.82	376.5	5.34×10^{-4}

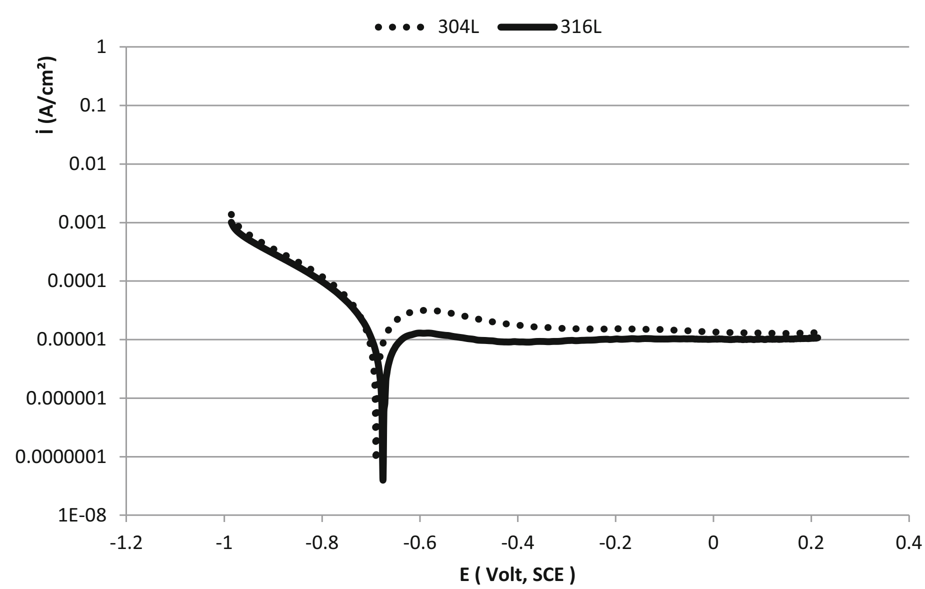


Fig. 3 The current–potential *curves* of AISI 304L and AISI 316L steels in raw juice

Results of measurements conducted during 2010–2011 campaign period

In this campaign period, corrosion resistance of AISI 304L, electroless Ni-coated St 37.2 and St 37.2 samples in different types of juices were determined by weight loss, EIS, LP and potentiodynamic measurement methods. Electroless Ni deposits are widely used in different industries for their unique combination of properties such as wear resistance, corrosion resistance and higher hardness [15]. The anticorrosive behavior of these deposits gained greater importance and applicability [16]. Therefore, in this campaign period, corrosion resistance of nickel-coated St 37.2 sample was also evaluated for considering replacement of the materials used in Ankara Sugar Factory.

Table 4 shows corrosion rates of St 37.2 and AISI 304L steels determined by weight loss measurement technique. Highest corrosion rates were recorded in raw juice and the lowest corrosion rates were recorded in juices obtained from 2A evaporators in 2009–2010 campaign periods.

Figure 4 shows the Bode plots of AISI 304L, nickel-coated St 37.2 and St 37.2 samples obtained from raw juice. Similar Bode plots were also obtained for EIS measurements conducted in clarified juice (juice obtained after liming), in thin juice and in juice taken from 2A evaporator. Impedance data were analyzed using R(QR) equivalent circuit.

The values of impedance parameters derived from the fitting of equivalent circuit to experimental data are given in Table 5 which shows that corrosion resistance of electroless nickel-coated St 37.2 steel was increased compared to the uncoated St 37.2 steel. However, corrosion resistance of electroless nickel-coated St 37.2 steel is much lower than corrosion resistance of AISI 304L steel. This implies that electroless nickel coating is not feasible in juice medium as substation of St 37.2 steel. According to the results given in Table 5, corrosion rates of the studied materials depend on pH and brix (solid concentration in the juice). To evaluate the effect of pH on the corrosion, measured corrosion rates in raw juice, clarified juice and

Table 4 The results of weight loss corrosion test obtained in juice samples taken from various units during 2010–2011 campaign period

Juice	Metals	Briks	pH	Corrosion rate determined by weight loss test (mpy)
Raw juice	AISI 304L	14.7	6.8	0.0056
Raw juice	St 37.2	14.7	6.8	0.2100
Raw juice after liming	AISI 304L	14.9	9.0	0.0040
Raw juice after liming	St 37.2	14.9	9.0	0.0900
Thin juice	AISI 304L	14.1	8.8	0.0042
Thin juice	St 37.2	14.1	8.8	0.0081
2A Evap.	AISI 304L	30.2	8.9	0.0029
2A Evap.	St 37.2	30.2	8.9	0.0370

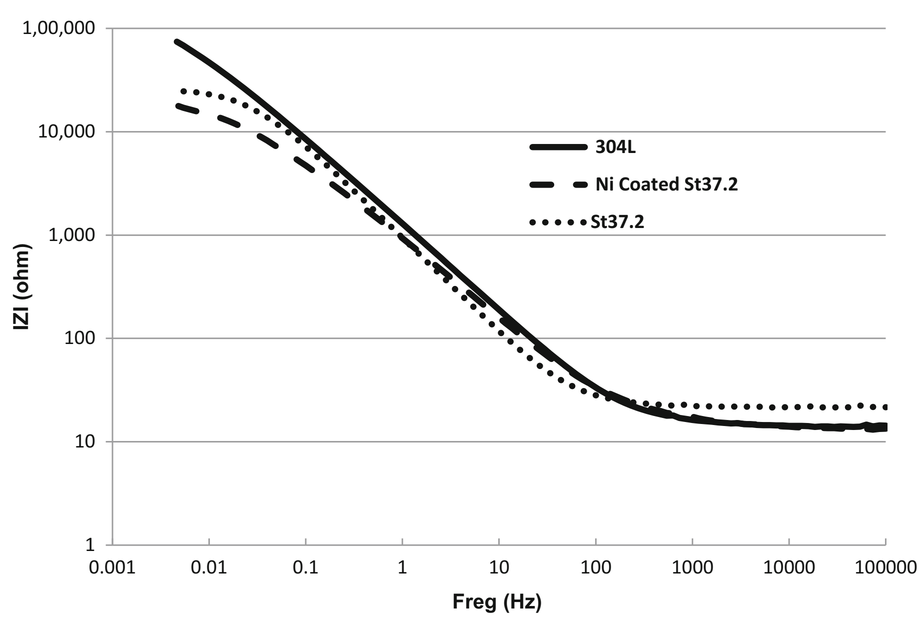


Fig. 4 The *Bode curves* of AISI 304L, St 37.2 and Ni-coated St 37.2 electrodes in raw juice

Table 5 The EIS circuit analysis results obtained in juice samples taken from various units during 2010–2011 campaign period by fitting the impedance spectra to the R(QR) circuit

	Metals	Briks	pH	R_s (kΩ cm^2)	Q_1 (Ss^{-n}/cm^2)	n	R_{ct} (kΩ cm^2)	χ^2
Raw juice	AISI 304L	14.7	6.8	0.0326	0.00004	0.72	218	6.21×10^{-4}
Raw juice	Ni coat.	14.7	6.8	0.0280	0.00046	0.87	8.1	5.96×10^{-4}
Raw juice	St 37.2	14.7	6.8	0.0340	0.00074	0.73	4.9	6.13×10^{-4}
Raw juice after liming	AISI 304L	14.9	9.0	0.0240	0.00013	0.82	254	2.71×10^{-4}
Raw juice after liming	Ni coat.	14.9	9.0	0.0213	0.00003	0.88	13.4	3.12×10^{-4}
Raw juice after liming	St 37.2	14.9	9.0	0.0189	0.00034	0.78	11.7	4.52×10^{-4}
Thin juice	AISI 304L	14.1	8.8	0.0019	0.00008	0.81	256	2.67×10^{-4}
Thin juice	Ni coat.	14.1	8.8	0.0171	0.00012	0.89	25	3.12×10^{-4}
Thin juice	St 37.2	14.1	8.8	0.0867	0.00003	0.66	125	4.52×10^{-4}
2A Evap.	AISI 304L	30.2	8.9	0.0136	0.00023	0.83	273	6.13×10^{-4}
2A Evap.	Ni coat.	30.2	8.9	0.0220	0.00020	0.91	26.6	5.21×10^{-4}
2A Evap.	St 37.2	30.2	8.9	0.0139	0.00027	0.76	20.5	4.67×10^{-4}

Table 6 The result of linear polarization measurements of juice samples taken from various units obtained during 2010–2011 campaign period

Juice	Metals	Briks	pH	E_{corr} (mV)	i_{corr} (μA)	R_p (kΩ cm^2)
Raw juice	Ni coat.	14.7	6.8	−332.6	394.0	6.4
Raw juice	St 37.2	14.7	6.8	−705.3	770.0	2.2
Raw Juice after liming	Ni coat.	14.9	9.0	−280.6	189.4	13.8
Raw juice after liming	St 37.2	14.9	9.0	−313.5	195.0	11.3
Thin juice	Ni coat.	14.0	8.8	−335.9	124.1	21.0
Thin juice	St 37.2	14.0	8.8	−257.8	19.8	136.0
2A Evap.	Ni coat.	30.2	8.9	−337.6	98.1	26.6
2A Evap.	St 37.2	30.2	8.9	−401.3	120.8	21.6

thin juice should be compared with each other. In these juice mediums, brix content can be considered to be almost equal. Highest corrosion rates were recorded in raw juice, which has the lowest pH value. Our results are consistent with those obtained by Gupta et al. [17]. They performed a study to evaluate the effect of pH on corrosion rate of mild steel in raw, draft and clarified juice. They have found that the corrosion rate was highest for raw cane juice followed by clarified juice and draft juice [18], respectively. When the measured corrosion rates of AISI 304L and nickel-coated steels in juice taken from 2A evaporator (measured at room temperature), and in clarified juice are compared with each other, it can be seen that the lowest corrosion rates are recorded in juice taken 2A evaporator. pH values of these three juice mediums are almost same. However, the juice taken from 2A evaporator has the highest brix and highest corrosion resistance. This result is consistent with the result obtained by Bajpai et al. [19]. They reported that corrosion rate linearly increases with decrease in brix. Brix contains organic substances such as sucrose, amino acids, betaine, glucose, fructose that acts as in inhibitors for the corrosion of steel in corrosive medium. Similarly Date Palm Fruit Juice due to presence of mentioned organic substances acts as inhibitor for the corrosion Aluminum Alloy in 3.5 % NaCl [20]. However, corrosion resistance of St 37.2 in juice taken from 2A evaporator was found to be lower than the corrosion rate in thin juice. Evaporators are working with high vacuum which is an oxygen-free environment. Therefore, electrochemical experiments conducted in juice taken from 2A evaporator have a medium that has low oxygen content. Formation of porous nature of oxide film on St 37.2, which has a protective character, is not much feasible. So, lower corrosion rate was recorded in juice taken from 2A evaporator although it has the highest brix content.

Polarization resistance measurements were also conducted for St 37.2 and nickel-coated St 37.2 for the corrosion measurements in various juices. Table 6 shows the result of Linear Polarization measurements. As it can be seen from the table, the highest corrosion rates were recorded for samples in raw juice. On the other hand, St 37.2 steel has the least corrosion rate. Table 6 also shows that measured E_{corr} values of St 37.2 in juice mediums (except in thin juice) are more negative than that of

Fig. 5 The current–potential *curves* of AISI 304L, St 37.2 and Ni-coated St 37.2 steels in 2A evaporator

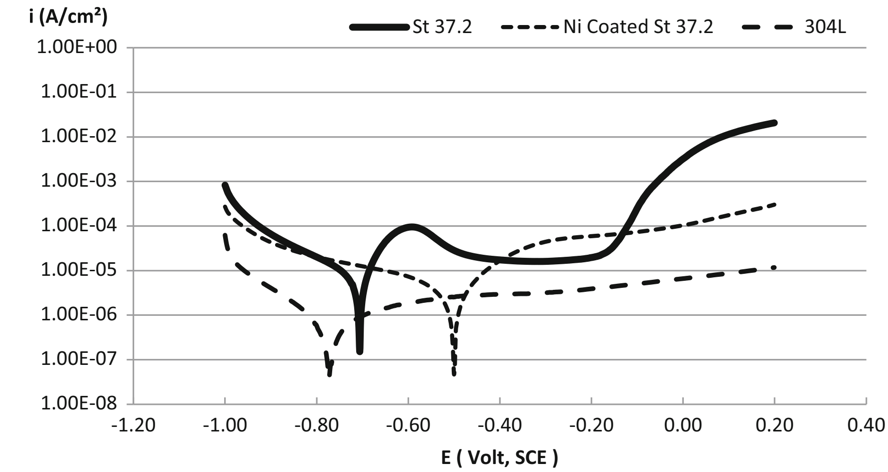
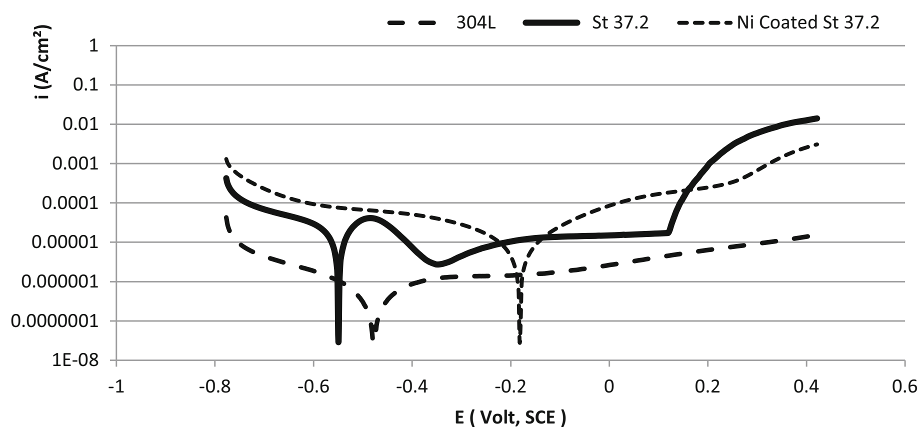


Fig. 6 The current–potential *curves* of AISI 304L, St 37.2 and Ni-coated St 37.2 steels in clarified juice



measured E_{corr} values of nickel-coated St 37.2 indicating lower corrosion resistance of St 37.2. Similarly, for carbon steel negative E_{corr} value was more thus higher corrosion rate than the stainless steel alloys was recorded in raw sugar juice environment [21]. Potentiodynamic polarization measurements were also conducted for St 37.2 and nickel-coated St 37.2 steels. Lowest current densities and most noble Open Circuit Potential were recorded for AISI 304L steel indicating highest corrosion resistance in the studied juice mediums. However, for St 37.2 drastic current increase in the polarization curves shown in Figs. 5 and 6 was observed at more anodic potentials from Open Circuit Potential in juice taken from 2A evaporator and in clarified juice. pH values of these mediums are about 9 and obtained Open Circuit Potential values are close to −300 mVversus SHE. Thus, this region in Fe–H_2O system in Pourbaix Diagram corresponds to $Fe_2O_3{\cdot}H_2O$ phase [22]. Due to non-adherent porous nature of this formed oxide film on St 37.2, destruction of this film at more noble potentials was observed as current increase [23].

Results of measurements conducted during 2011–2012 campaign period

In this campaign period, corrosion resistance of AISI 304L and St 37.2 steels in various juice mediums was evaluated using weight loss EIS, LP, and potentiodynamic measurements. This comparative study of corrosion of AISI 304L steel and St 37.2 steel in sugar juices is to probe the feasibility of replacing St 37.2 with AISI 304L in different parts of Ankara Sugar Factory.

Table 7 shows corrosion rates of St 37.2 and AISI 304L steels determined by weight loss measurement technique. Highest corrosion rates for AISI 304L were recorded in raw juice and the lowest corrosion were recorded in juice taken from 2A evaporators as in 2009–2010 and 2010–2011 campaign periods.

Figure 7 shows the Bode plots of AISI 304L, St 37.2 samples obtained from raw juice. Similar Bode plots were also obtained for EIS measurements conducted in clarified juice, thin juice and the juice taken from 2A evaporator.

Table 7 The results of weight loss corrosion test obtained in juice samples taken from various units during 2011–2012 campaign period

Juice	Metals	Briks	pH	Corrosion rate with coupon test (mpy)
Raw juice	AISI 304L	15.6	5.9	0.0061
Raw juice	St 37.2	15.6	5.9	0.3700
Raw juice after liming	AISI 304L	14.9	9.0	0.0038
Raw juice after liming	St37.2	14.9	9.0	0.0840
Thin juice	AISI 304L	14.8	8.9	0.0038
Thin juice	St 37.2	14.8	8.9	0.0075
2A Evap.	AISI 304L	30.3	9.1	0.0037
2A Evap.	St 37.2	30.3	9.1	0.0410

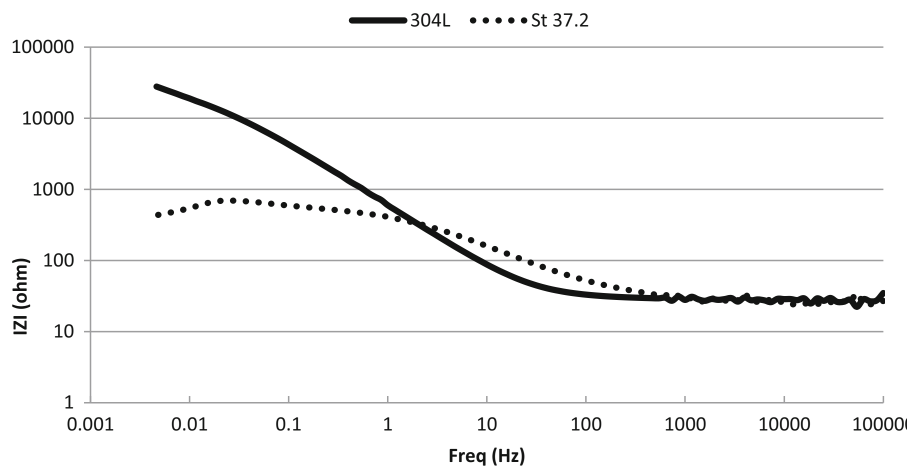


Fig. 7 The *Bode curves* of AISI 304L and St 37.2 electrodes in raw juice

Table 8 The EIS circuit analysis results obtained in juice samples taken from various units during 2011–2012 campaign period (stabilization made with R(QR) circuit

	Metals	Briks	pH	R_s (kΩ cm^2)	Q_1 (Ss^{-n}/cm^2)	n	R_{ct} (kΩ cm^2)	χ^2
Raw juice	AISI 304L	15.6	5.9	0.1370	0.00007	0.87	178.0	4.88×10^{-4}
Raw juice	St37.2	15.6	5.9	0.1240	0.00010	0.76	3.1	5.08×10^{-4}
Raw juice after liming	AISI 304L	14.9	9.0	0.0860	0.00006	0.76	267.0	1.67×10^{-4}
Raw juice after liming	St 37.2	14.9	9.0	0.1040	0.00006	0.81	11.5	3.55×10^{-4}
Thin juice	AISI 304L	14.8	8.9	0.0910	0.00003	0.75	283.0	1.19×10^{-4}
Thin juice	St 37.2	14.8	8.9	0.0824	0.00009	0.66	145.0	9.10×10^{-4}
2A Evap.	AISI 304L	30.3	9.1	0.0590	0.00002	0.73	288.0	3.84×10^{-4}
2A Evap.	St 37.2	30.3	9.1	0.0700	0.00031	0.65	26.1	3.90×10^{-4}

The values of impedance parameters derived from fitting of R(QR) equivalent circuits are given in Table 7. Potentiodynamic polarization measurements were also conducted for AISI 304L and St 37.2 in clarified juice (juice obtained after liming), in thin juice and in juice taken from 2A evaporator. The polarization curves obtained show similar behaviors to those obtained in 2010–2011 campaign period.

Polarization resistance measurements were also conducted for St 37.2 for the corrosion measurements in various juice mediums. Examination of polarization resistance values given in Table 8 shows that the highest corrosion resistance was recorded in thin juice and the lowest corrosion resistance values are recorded in raw juice medium.

Conclusion

In the present study, corrosion resistance of AISI 304L, AISI 316L, St37.2, and nickel-coated St 37.2 steel in different juice mediums of Ankara Sugar Factory was evaluated using weight loss and electrochemical techniques such as Electrochemical Impedance Spectroscopy, Linear Polarization and Tafel Extrapolation methods. TP method is not found to be applicable for obtaining quantitative corrosion rates; whereas LP method was applicable for obtaining qualitative corrosion rates of St 37.2 and nickel-coated St 37.2 steel. However, EIS method was found to be suitable for determining quantitative corrosion rates for all steel types included in the study. Results obtained from EIS measurements and weight loss coupon test had the same trends. According to these rates, it can be concluded that corrosion rates were dependent on pH and brix content of the sugar juice. Thus, the highest and the lowest corrosion rates were recorded for raw juice and thin juice, respectively. St 37.2 steel had the fastest corrosion rate while stainless steel AISI 316L corroded has the least juices extracted from beet sugar as evaluated by weight loss and electrochemical techniques. For economic reasons, the low-cost AISI 304L steel can be used in Ankara Sugar Factory since it has slightly lower corrosion resistance compared to AISI 316L steel.

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